

Mu'tah University

Deanship of the Graduate Studies

Physical and Geometrical Elements of the Visually Close Binary System HIP64838

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Dedication

I dedicate this work to my parents, brothers and sisters.
My friends: Jasser Suleiman, Anas Suleiman, Mohammad Dwarej , Hussam Abu-Shattal , with my best wishes for all of them.

Ahmad Ali Abu-Shattal

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I glorify God almighty who gave me courage throughout and patience to finish the work of this thesis and to progress all over my life.

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To Mosa Ali Al-Naimat My humble respect, to all people who shared a moment of happiness with me.

Thanks.

Ahmad Ali Abu-Shattal

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Abstract

Physical and Geometrical Elements of the Visually Close Binary System HIP64838

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Mu’tah University, 2012

This study aimed to estimate the physical and geometrical elements of the components of the visually close stellar binary system HIP 64838. depending on the comparison and best fit between the entire observational spectral energy distribution for the system, and the synthetic ones created by atmospheric modeling of the components of the binary system using a grid of Kurucz's blanketed models.

The synthetic magnitudes of both components were calculated using the Johnson-Cousins, Stromgren, and Tycho photometrical systems and entire spectral types are presented and compared with those of Hipparcos catalogue and SIMBAD.

These parameters will improve our knowledge about binary systems, their formation and evolution.

الملخــص

الخصائص الفيزيائية والهندسية للمنظومة النجمية الثنائية HIP64838

أحــمد علــي أبــوشــتال

جامعــة مؤتــة، 2012

تهدف هذه الدراسة لمعرفة الأنظمة النجمية الثنائية وتاريخها وأنواعها وكيفية تكونها وتطورها والطرق الفلكية الحديثة لحساب خصائص تلك الأنظمة.

ومعرفة الخصائص الفيزيائية والهندسية للنظام النجمي الثنائي (HIP64838)، وذلك عن طريق عمل مقارنة بين توزيع الطاقة الطيفي المرصود والتوزيع الطيفي للطاقة الناتج عن نمذجة الغلاف باستخدام (نموذج كوروتز)، ومن ثم حساب المعاملات اللونية لهذا النظام ومقارنتها مع الأنظمة الطيفية تيخو وجونسون وأخرون لتأكد من دقة وصحة التحليل الطيفي.

وهذه المعلومات تزيد من معرفة (الكتلة، درجة الحرارة، الأقطار، اللمعانية، الكثافة، الأقدار الظاهرية، الأقدار المطلقة، العمر) للنجمين المكونين لهذا النظام، مما يمكننا أيضا من معرفة الغازات المكونة للغلاف النجمي ونوع تلك الغازات.

Chapter One
Introduction

1.1 Introduction

Binary systems give a unique possibility for the direct determination of the complete set of stellar parameters without depending on any statistical relations. Such possibility, however, can only be applied for objects having a possibility to be observed by means of different observational methods.

The correlation between spatial locations, dynamical characteristics, ages and metallicities of the main sequence stars (MS) is the key for the understanding of the chemical and dynamical evolution of our Galaxy.

And there are some basic parameters and fundamentals must be reviewed before starting this study.

1.1.1 Coordinate Systems

Altitude and Azimuth. The altitude is defined relative to the horizon, and azimuth is as the angle from the horizon to the position of the object. The altitude and azimuth of an object are particular to the observing location and the time of observation.

Right ascension and declination. Declination (δ) is like latitude on the Earth, It measures the angle north and south of the celestial equator (an imaginary line in the sky directly over the Earth's equator).

Right ascension (α) is analogous to longitude. The ecliptic is the plane of the solar system, or the path that the Sun follows in the sky. Right ascension is measured in hours, minutes, and seconds to the east of the vernal equinox. There are 24 hours of right ascension in the sky; each hour on Earth changes the right ascension of the meridian by just less than 1 hour. (Palen, 2001)

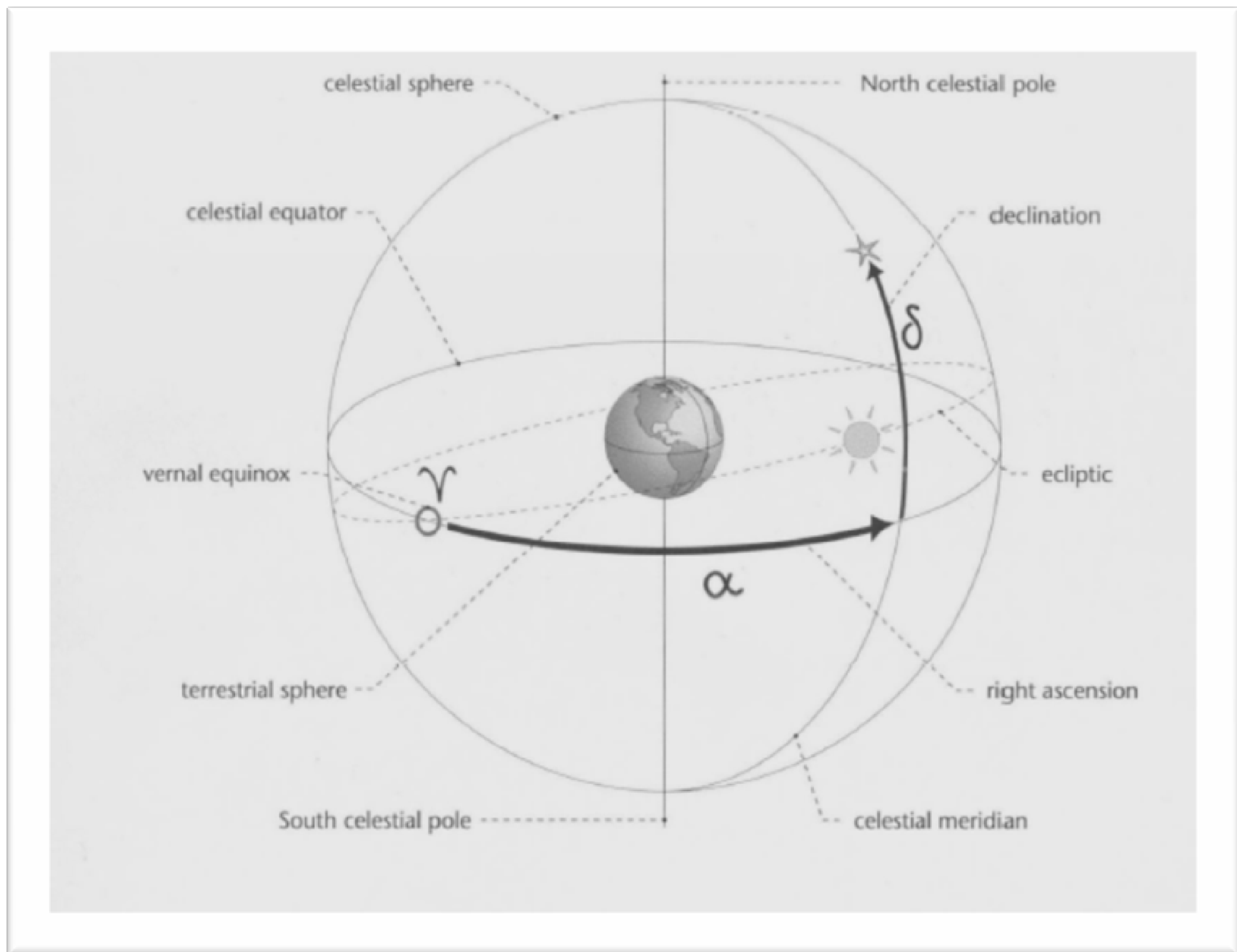


Figure 1.1
Celestial Coordinate System

1.1.2 The Doppler Effect

The wavelength of light that an observer sees coming from an object depends on the motion of the object relative to the observer. If either the object or the observer moves along the line of sight , the wavelength will change. The relationship between motion and observed wavelength is called the **Doppler Effect**.

When an object is approaching or moving away, the wavelength of the light it emits (or reflects) is changed. The shift of the wavelength $\Delta\lambda$ is directly related to the velocity(v) of the object according to the follwing relation :

$$\Delta\lambda = \frac{\lambda_0 v}{c}$$

where λ_0 is the wavelength emitted if the object

is at rest and v is the component of the velocity along the ‘‘line of sight’’ or the ‘‘radial velocity.’’ Motion perpendicular to the line of sight does not contribute to the shift in wavelength. This equation holds when the velocity of the object is much less than the speed of light. For approaching objects, $\Delta\lambda$ is negative, and the emitted wavelength appears shorter (‘‘blue-shifted’’). For receding objects $\Delta\lambda$ is positive, and the emitted wavelength appears longer (‘‘red-shifted’’). (Palen, 2001)

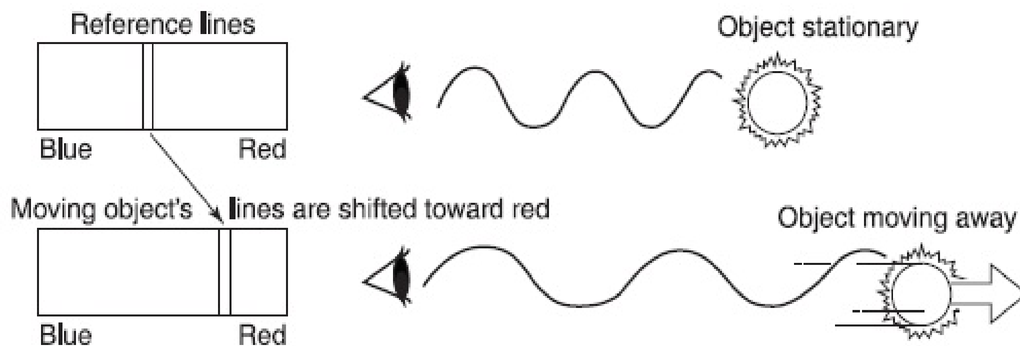


Figure 1.2
The Doppler Effect

1.1.3 Astronomical Catalogue

Catalogue, astronomical Tabular compilation of stars or other deep-sky objects, giving their celestial coordinates and other parameters, such as magnitude (Moore, 2002).

In my thesis I got the basic information from Hipparcos catalogue (Hipparcos is an astrometric satellite of the European Space Agency (ESA)) .

1.1.4 Hertzsprung – Russell Diagram

A famous diagram, called the Hertzsprung Russell (hereafter H – R) diagram, shows the relation between the luminosity and the effective temperature of stars.

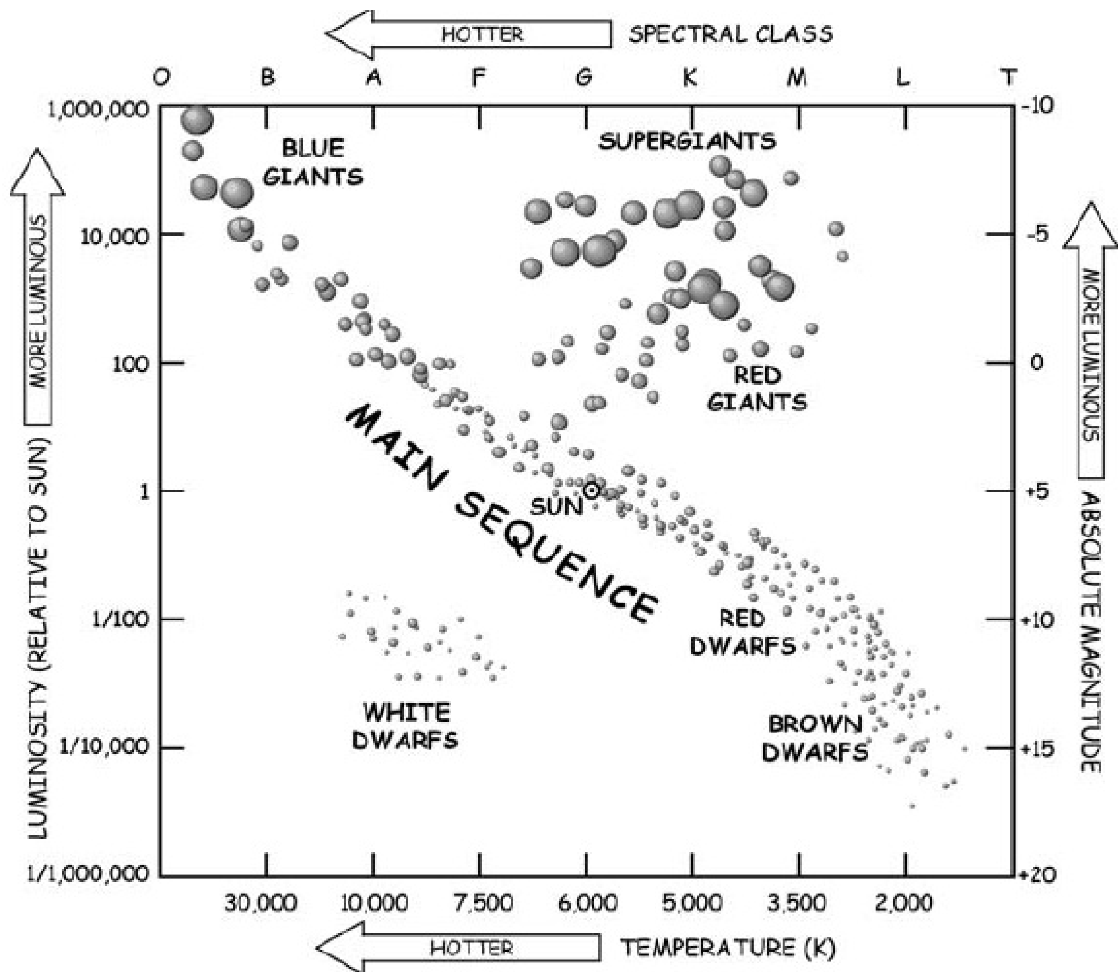


Figure 1.3
H-R diagram

H-R Summary:

In the century since the bases of HR diagrams were first developed, they have become invaluable in the study of stars. For astronomers, a star's location in an HR diagram provides the same depth of insight as for chemists examining an element in the periodic table. It relates hydrogen fusing stars' temperatures, colours and spectral classes with their luminosities, thereby providing insights into their evolution. A star's position in the diagram can indicate its composition, surface temperature, intrinsic brightness, size, mass, lifetime, and evolutionary status. That's a lot of information from a diagram. It's been invaluable in determining the age of various star clusters. Apparent magnitudes can be used if absolute magnitudes are not available, since all stars in a cluster are roughly equally distant from observer.

1.2 State of the art

It is very difficult to measure the mass of a star; it can only be done for binary stars. In a binary system, both objects move around center of mass of the system, rather than one object "orbiting" the other object.

Hipparcos catalogue is the most full and reliable source of the information about stellar parallaxes - it contains more than 20000 parallax measurements for nearby stars with distance estimation errors better than 10%. However, binary systems parallax determinations were distorted by their orbital motions, the reason why their real accuracy was much lower than those of single stars. So, Speckle-Interferometry remains the main method of determination of binary stars' visual orbits.

For more details about previous basic concepts see (appendix I).

The combination of interferometric magnitude difference results with the spectrophotometric data allows building individual model atmospheres for each component of a binary system.

To know more than about Astronomical Catalogue see (appendix I).

1.3 Aims of the Study

The main goal of this thesis is to estimate the complete set of the Physical and Geometrical Elements of the components of the VCBS (Visually Close Binary System) Hip64838, in addition to a modification to its parallax measurement by Hipparcos. Data will enable us to come closer to the understanding of formation and evolution of this system.

1.4 Earlier Studies

Few VCBS's were analyzed using this technique.

(Al□Wardat, 2007)analyzed the two systems COU1289 and COU1291, (Al□Wardat, 2009)analyzed the system Hip11352, (Al-Wardat & Widyan, 2009) analyzed the system Hip11253 (HD14874). (Balega, et al., 2004) introduced orbital analyses of some VCBS's.

1.5 Methods

The thesis will focus on getting the physical and geometrical elements of the components of the system, which is already known as a resolved binary system.

The technique depends on using observational entire *Spectral Energy Distribution* (SED) of the system, along with atmospheres modeling, to get the individual SED for each component, and hence to get their physical and geometrical elements.

The system has been selected according to the following requirements:

1- The system has a separation less than 0.5 arcsec (where systems of higher separation usually studied by other simple techniques).
2- The system has a measured magnitude difference between its components, which is the key of this technique.
3- It has a good built the orbit as a result of the speckle interferometric studies, which will be used as a reference and a guideline especially in determining the masses.

The system Hip64838 is listed among *Hipparcos Catalogue, The Fourth Catalogue of Interferometric Measurements of Binary Stars*, *The Sixth Catalogue of Orbits of Visual Binary Stars* and *The Second Photometric Magnitude Difference Catalogue.*

The system also has a measured wide range (from about 3500Å to 9000Å) entire visual spectral energy distributions (Al-Wardat, 2002a, 2002b, 2002c). This entire observational SED will be used to compare the estimated synthetic SED's.

The procedure will focus on the combination between the speckle interferometric magnitude differences, the entire spectral energy distributions and the atmospheres modelling of the system, in order to build theoretical individual spectral energy distributions for each of its components.

The method also depends on getting the best fit between the observational entire SED's and the theoretical ones built using ATLAS9 line-blanketed plane-parallel model atmospheres program by (Kurucz, 1993). Where the theoretical SED of each component will be constructed alone, and then combined with that of the second component to get the entire SED using the following relation (Al-Wardat, 2002a, 2003):

$$F_\lambda = \left(\frac{R_a}{d}\right)^2 \left[H_\lambda^a + H_\lambda^b \left(\frac{R_b}{R_a}\right)^2 \right]$$

where H_λ^a and H_λ^b are the fluxes from a unit surface of the corresponding component R_a and R_b are their radii and d is the distance to the system in parsecs. Hence the complete list of parameters of the systems' components (effective temperature, luminosity, spectral type, mass, gravity acceleration and age) will be available. The ages of the systems can then be estimated using (Girardi, Bressan, Bertelli, & Chiosi, 1999) evolutionary tracks and isochrones, both with and without overshooting depending on the used models of atmospheres.

1.6 Expected results:

By this, we will be having the complete set of the individual fundamental parameters of the two components (effective temperatures, luminosities, spectral types, masses, gravity accelerations and ages).

These estimated parameters will be the most detailed and accurate ones ever estimated for the studied system. Knowledge will improve the picture of the formation and evolution of this system.

Chapter Two
Theoretical Background

2.1 Binary star system

The importance of binary stars arises from the fact that more than 50% of the galactic stellar systems are binary or multiple star systems(Al Wardat, 2007), binary star refers to a system containing two stars held together by their mutual gravitational attraction, revolve in close elliptical orbits around their common center of gravity and have a common proper motion through space.

The system called a closed binary system is one where the angular separation between the two stars is very small and there is a large tidal interaction between two stars. This is distinguished from another type of star system, a visual binary star, for which the observer can clearly resolve two components and measure their apparent relative motion.

2.2 The Study of Binary Stars

Binary systems have been studied for a few centuries. It is credited to John Goodricke (1783) for his identification that Algol is an eclipsing binary with a two-magnitude variation with a period 68.8 hours. William Herschel published a report in 1802 and 1803 on his 40-year observing programme on double stars that he did with his sister Caroline. He demonstrated that some of the double stars they observed were in orbits that are in accordance with Newton's laws. These systems are now called visual binaries. Herschel (1802) first introduced the term binary star from this work. From the nineteenth century, many methods were used to study binary systems. The development of instruments in astronomy has made the acquisition of data more effective, the most commonly used observational techniques are astrometry, photometry, spectroscopy, Speckle Inter ferometry, and Spectrophotometry.

2.3 Why do we study binary star?

There are many reasons for studying binary stars:

It plays an important role in studying the formation, evolution and mass loss of stars. The spatial arrangement of the orbital planes of wide visual binaries in clusters or in small regions in the galaxy may play a role in interacting galactic dynamics (Lippincott 1992).

And it is also important because of the information it can provide. One of the most important fundamental properties of a star is its mass. The gravitational interaction between stars in a system causes the stars to orbit,

which can be detected through the variation of their positions and velocities. Stellar masses can be determined directly from their gravitational interaction. It also provides information about the separation between stars in a system. Some binary systems have a variation in brightness that can inform us about the sizes of stars. Other fundamental properties of stars can be determined depending on the method of observation and analysis.

2.4 Formation of Binary Stars

Any theory that aspires to explain how stars are born must also explain why the majority of stars in the Galactic disk are members of multiple-star systems, with the majority of those binary-star systems(Abt & Levy, 1976) . This is clearly a property that goes back to stellar birth, because newly-formed stars are also predominately in multiple-star systems. Stars do not pick up companions as they age. Either stars capture their companions shortly after birth, or they are born into multiple-star systems(White & Ghez, 2001) .

Binary-star systems have two properties that strongly impact theories of star formation. First, binary-star systems are small in size, with the separations between stars ranging from much less than 1 AU to several thousand AU. Second, for systems with short periods, the mass of the smaller of the two stars in a binary system is generally close to the primary star's mass, averaging half of the primary-star's mass, but, for systems with long periods, the mass is generally small, with a distribution of values similar to the distribution of stellar masses of isolated stars.

In recent years theorists have explored four theories for binary-star birth: *the capture of one star by another*; *the splitting of a star into two stars*; *the collapse of a star's accretion disk to a companion star*, *and the fragmentation of a collapsed molecular cloud into multiple stars*(Tohline, 2002) . The last-three theories treat the birth of a binary system as part of the birth of a star.

The first theory—the capture of a star by a second star—can explain the creation of binary stars in the dense globular clusters, where the gravitational potential energy liberated in the formation of a binary star "heats" the cluster, but it cannot explain the binary systems in the Galactic disk. The problem is that a star cannot capture another star unless kinetic energy is expelled from the system. A third star can be the sink for this kinetic energy, but in the Galactic disk the probability is low that three stars would come together at the same time in a way that leaves two of these stars bound together. Even with the higher stellar densities in star-forming regions, the rate of capture is too low to produce a high number of binary

systems with young stars. Tidal heating of the stars can expel kinetic energy from the system, but for tidal forces to dissipate enough energy to cause stellar capture requires the stars to pass very close to one-another, which is a low-probability event. One way around this close-encounter problem is to tidally-heat the accretions disks orbiting each star instead of the stars themselves. Accretions disks are observed orbiting newly-formed stars. These disks are seen by the infrared radiation they emit. They take up angular momentum from the new star, allowing the star to become a slowly-rotating pressure-supported sphere. One can imagine that as a pair of young stars with accretion disks passes each-other, they raise tides in each-other's accretion disks, dissipating kinetic energy. Simulations of this process, however, find that in such an event the accretion disks are disrupted without extracting enough kinetic energy to gravitationally bind the stars. For these reasons, one does not expect stars to capture one-another at a great rate, and certainly not rapidly enough to account for the binary-star systems containing stars that are only several million years old.

The second theory—a rapidly-rotating star can split into two stars—is a theory that is over a century old. It appears to be out of favor in the broad community, although some researchers are still pursuing it. The idea is that a rapidly-spinning spherical star is unstable, distorting first into a bar shape, and then into a barbell shape. The mass that accumulates at each end of the barbell becomes a star, so that the system evolves into a contact binary star. As each star contract to its main-sequence size, the binary system becomes detached. The problem is in getting the original star to evolve from a bar shape to a barbell shape; numerical simulations tend to find that angular momentum within the star is redistributed, and the star changes from a bar shape to a sphere orbited by an accretion disk.

The third theory—a second star forms from the accretion disk orbiting a newly-formed star—resembles the theory for planetary birth. As stated earlier, stars are born surrounded by accretion disks. The planets around the Sun and around other stars formed from these accretion disks. Compared to a star, the planets in a planetary system are very small. *Can an accretion disk give birth to something as large as a star?* Theorists have shown that such a birth is possible if the accretion disk is more massive than the central star it is orbiting. The idea is that after the central star forms from a molecular cloud, the accretion disk surrounding it continues to accumulate gas from the cloud. When the accretion disk becomes more massive than the central star, the disk becomes unstable, with the gas in the disk clumping to one side of the disk. This instability is driven by the self-gravity of the accretion

disk. Eventually all of the gas in the disk flows to one part of the disk to form the second star. The advantage of such a theory is that it naturally produces binary stars rather than systems with three or four stars, and it explains why the size of a binary-star system is comparable to the size of a planetary system.

The final theory—a molecular cloud collapses and fragments to form multiple stars—takes advantage of the fact that as a cloud contract, the length over which it is stable contracts more rapidly. Under the current theories of star formation, a star forms when the densest regions of a molecular cloud collapse through their own self-gravity. Whether a cloud is stable against collapse depends on whether it is larger or smaller than the Jeans length, which is set by the temperature and density of the gas. If a static cloud is larger than the Jeans length, it will collapse. If the cloud is much larger than the Jeans length, it will collapse into several pieces, with the initial size of each piece of order the Jeans length. The interesting feature of this fragmentation is that if a cloud cools as it contracts, the Jeans length for the cloud becomes much smaller than the size of the cloud. This has lead theorists to believe that a collapsing molecular cloud of several solar masses could fragment and give birth to a multiple-star system. The problem in this simple picture, however, is that as long as the cloud is collapsing, it cannot fragment. Computer simulations have shown that the density gradients that form as a cloud collapses prevent the cloud from fragmenting. Not unless the original cloud ceases its collapse and stabilizes itself at a smaller scale can fragmentation and collapse occur. Angular momentum provides the mechanism that halts collapse, causing the cloud to settle down as a large rotating disk. This disk fragments and collapses to form several stars that are gravitationally bound to each-other. The size of the system is set by the size of the stabilized cloud. Whether one can preferentially form binary stars with such a theory is not yet known.

As often happens in astrophysics with frequently-occurring phenomena, the birth of a binary star is difficult to replicate in the laboratory, which in this case is within a computers guts. Astrophysicists are unable to follow the computer realizations of the last-three theories for a sufficient length of time to see stars form. The problem is in the wide range of scales encountered in the problem. Spatially, one is following the three-dimensional evolution of a cloud that is parsecs in size down to a handful of stars separated by several AU and with radii of less than 0.01 AU, so the scale changes by a factor of 10 million. One is also following processes that occur on a variety of timescales. In particular, the gravitational free fall timescale in the densest regions of a molecular cloud

are several orders of magnitude shorter than the orbital timescale for the system. These widely-varying scales, which must be resolved within a computer simulation, are why a theory that is over one hundred years old cannot be definitively eliminated from consideration.

How many theories do we need? The different characteristics of binary systems with periods of more than 100 years from those of systems with periods of less than 100 years suggests that two different mechanisms give us binary stars (100 years corresponds to a semi major axis of around 22 AU for a 1 solar mass system). The researchers who found this difference between long- and short-period systems in the 1970s suggested that a short-period binary system is formed when a rapidly-rotating star split in two, and a long-period system is formed when a molecular cloud fragments.(Abt & Levy, 1976) More recently, researchers studying systems of young stars have claimed that molecular cloud fragmentation as the source of all binary-star systems is most consistent with their data.(White & Ghez, 2001) The issue remains unsettled, so we find ourselves with three plausible theories for the origin of binary stars in the Galaxy disk, two of which may be at work creating binary stars. If only one mechanism is at work, it is likely the fragmentation of molecular clouds, but if two are at work, then the collapse of an unstable accretion disk now seems the most likely process creating the short-period binary systems.

2.5 Classification of binary stars

Close binaries can be classified into various groups depending on the observational techniques employed. The techniques that are mainly used by astronomers to observe a binary star are astrometry, photometry and spectroscopy. The variation of a measurement from each technique can be analyzed and shows that the spot of light we observed is a member of a binary system classifies binary stars according to the observational means into the following categories (Ostlie, 1996):

2.5.1 Visual binaries

Visual binary is a binary system that has a relatively large angular separation. By making careful observations with telescopes, observers can see the changing of the stars relative positions (see figure2.1).

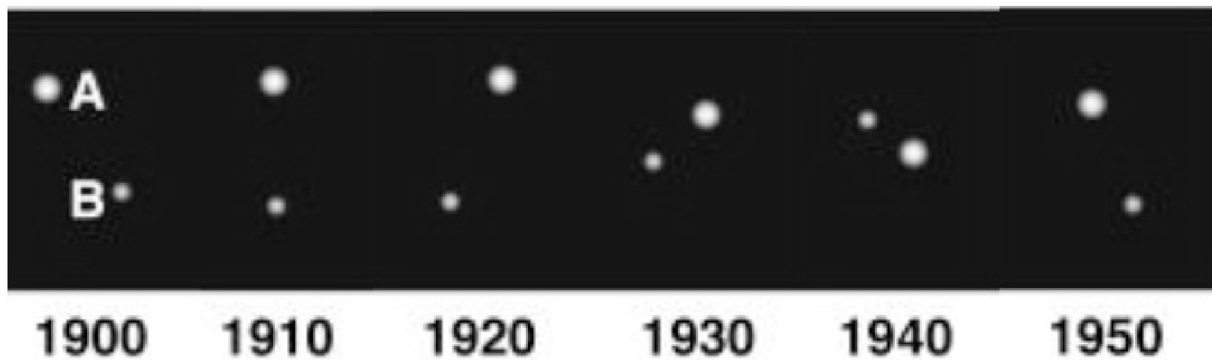


Figure 2.1
Simulated orbit of Sirius A & B

2.5.2 Spectroscopic binaries

Spectroscopic binaries are discovered by effects they produce in the combined spectrum of the binary system. There are two subgroups of spectroscopic binaries, the single-lined spectroscopic binary (SB1), where the spectrum of only one component is observed, and the double-lined spectroscopic binary (SB2) where both spectra are detected. This can be measured spectroscopically using the Doppler shift of absorption lines. They can be recognized at much greater distances than the visual binaries.

2.5.3 Eclipsing binaries

Eclipsing binaries are binary systems which have a periodic variation in their brightness. These systems orbit approximately perpendicular to the sky plane. When one star is passing in front of the other from the observer's line of sight, an eclipse will happen. The photometric observation of this kind of system will show the characteristic light curve of an eclipsing system. The analysis of a light curve can provide the inclination of a system, the ratio of luminosities, the photometric mass ratio, and the information about the stellar shapes. The absolute parameters of an eclipsing binary can be determined from its photometric and spectroscopic observations.

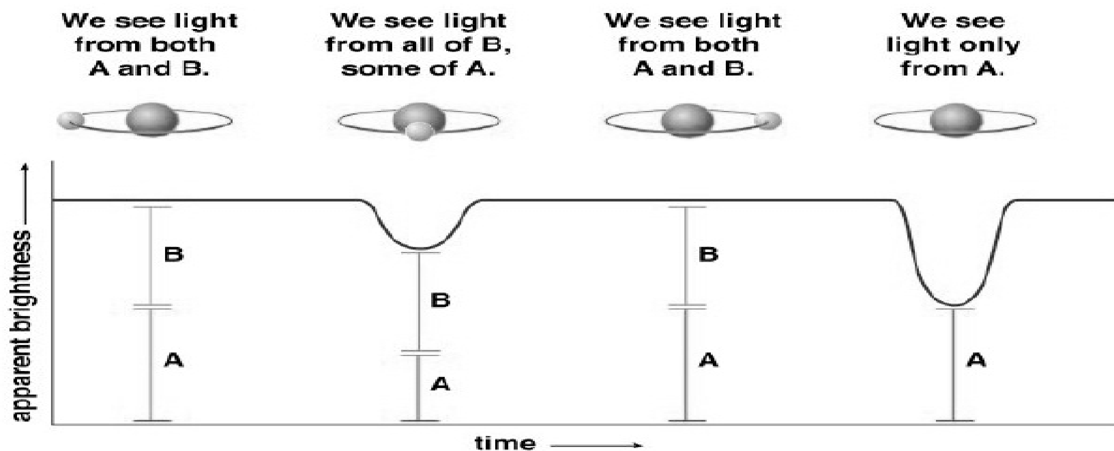


Figure 2.2
Eclipsing binaries

2.5.4 Astronomical binaries

Astronomical binaries; the binaries in which the companion cannot be seen directly, but from the periodic motion of the brighter star its presence can be inferred.

2.5.5 Interferometric binaries

Interferometric binaries; the binaries which are best measured by studying the interference patterns produced by the two stars.

There is an objection on this scheme of classification; however, is that it does not correspond to any obvious physical differences between the classes, i.e. a binary star may classify under more than one category. Another scheme classifies binary stars according to the separation between the pair into the following categories (Batten 1992; Plavic 1992).

2.5.6 Wide binaries

The binaries in which the separation of the two components is enough so that they don't affect each other evolution, like most of the visual binaries.

2.5.8 Close binaries

The binaries in which the two components interact in many ways and affect each other evolution, under this category we may insert many of the spectroscopic, eclipsing, and unusual types of objects resulting from interaction between the components of the close binary , like cataclysmic variables and X-ray binaries.

Binaries under this category can be classified into three sub-groups according to the Roche Model (Kopal, 1959) :

1. *Detached systems*; in which neither component fills its Roche lobe. see Fig 2.3a
2. *Semidetached systems*; in which the secondary fills its Roche lobe, while the primary (more massive) star is smaller than the Roche limit. See Fig 2.3b
3. *Contact systems*; in which both components appear to fill their Roche limit. see Fig 2.3c

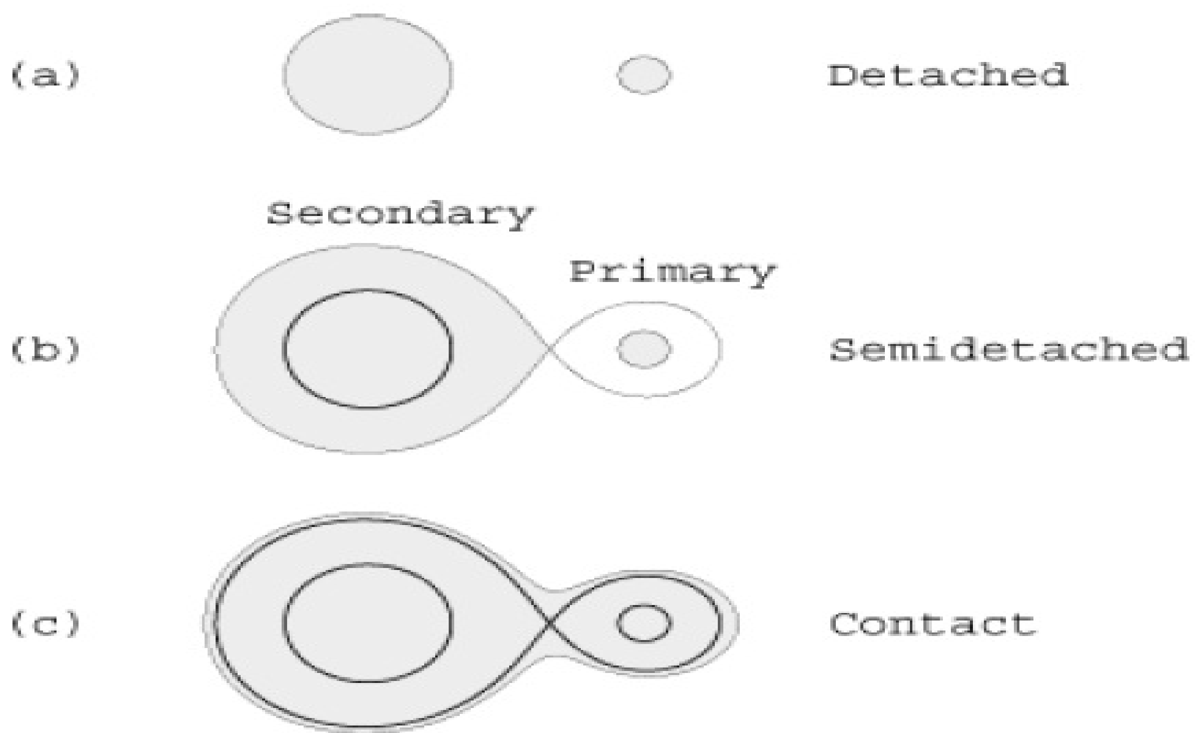


Figure 2.3
Close binaries

Chapter Three
Methodology

3.1 Introduction

There are many deferent observational and analytical methods for the estimation of the fundamental parameters of the components of a binary or a multiple system. But it is well known that the combination of different methods is more effective and productive than using one single method, whatever the way of the combination.

We applied equations on data to get statistical calculation and physical parameters of this system to modulate its atmosphere.

Using Atlas (Application) to form primitive sample for many temperatures and then gathering each two sample together to make Atmospheric modeling then we compare between Spectral Energy Distribution (SED) for the sample and the observational one by using Origin 8(Application) if there was accordance we use IDL programming to be sure about the properties of the star and then making the combination. When get the best fit we used the IDL program to confirms if this trial what we are looking for.

3.2 Effects of different parameters on synthetic SED's

Before building the synthetic spectral energy distribution for any star, we need to understand the effect of each of the different physical and geometrical parameters on the absolute flux of the star, which is represented by the spectral energy distribution.

3.2.1 Effects of the effective temperature on synthetic SED's

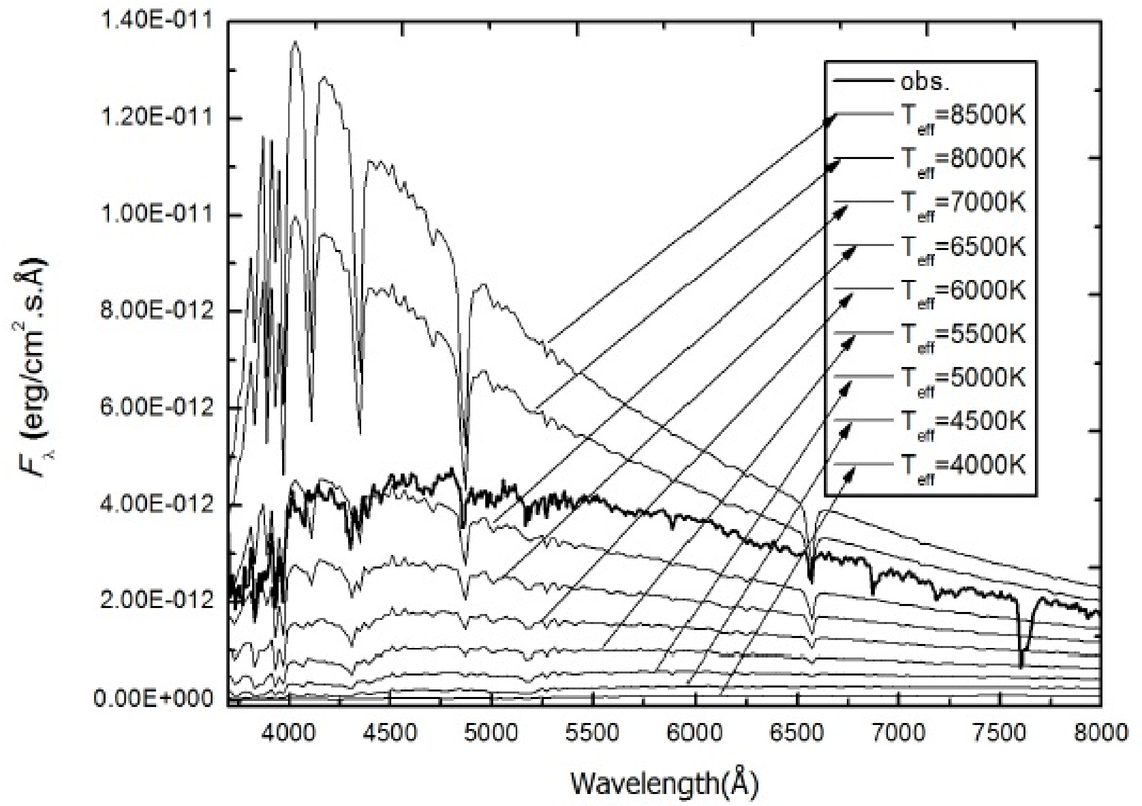


Figure 3.1
Effect of changing temperature on the SED of the star

3.2.2 Effects of the gravity acceleration (log g) on synthetic SED's

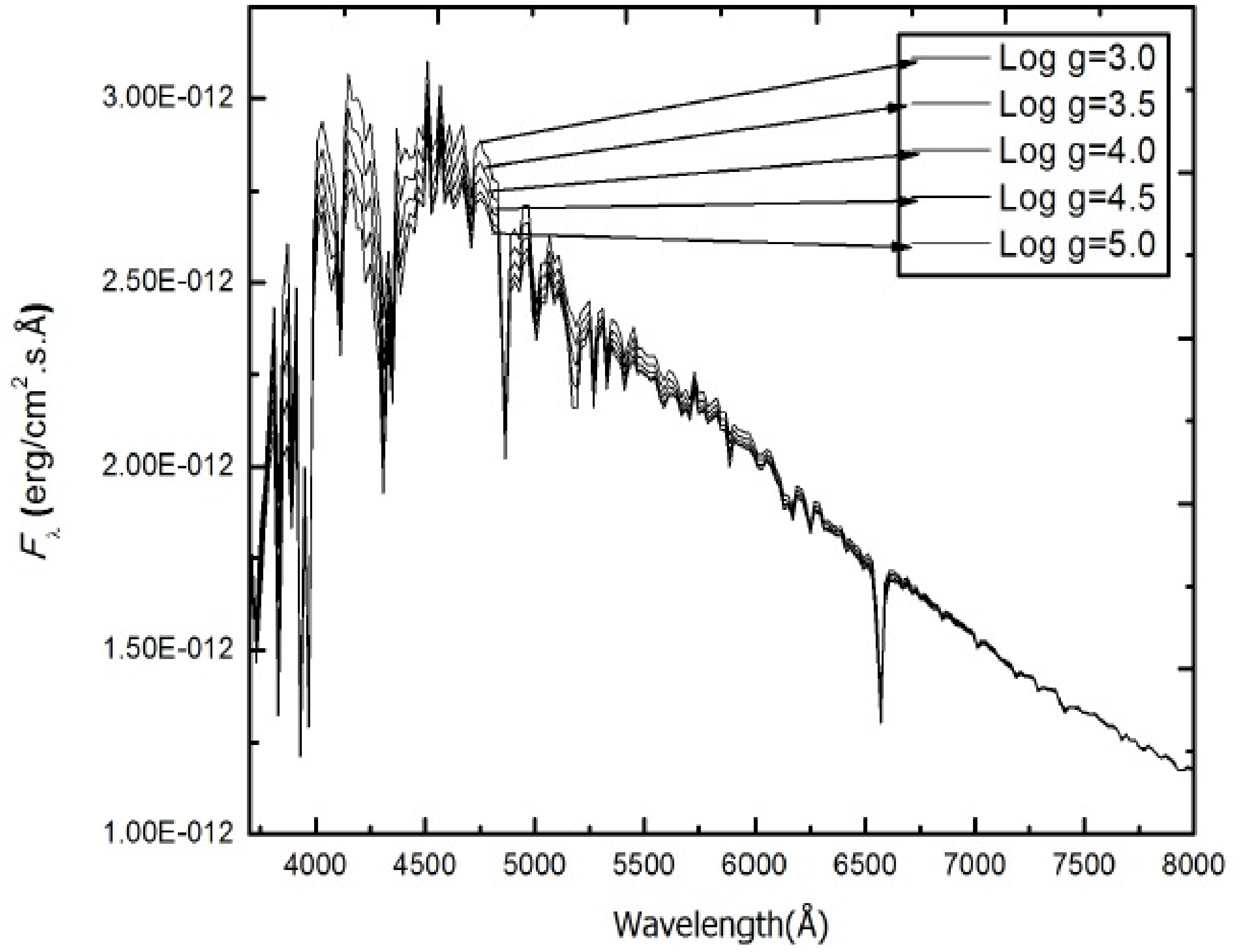


Figure 3.2
Effect of changing gravity acceleration on the SED of the star

3.2.3 Effects of changing the radius on the absolute flux

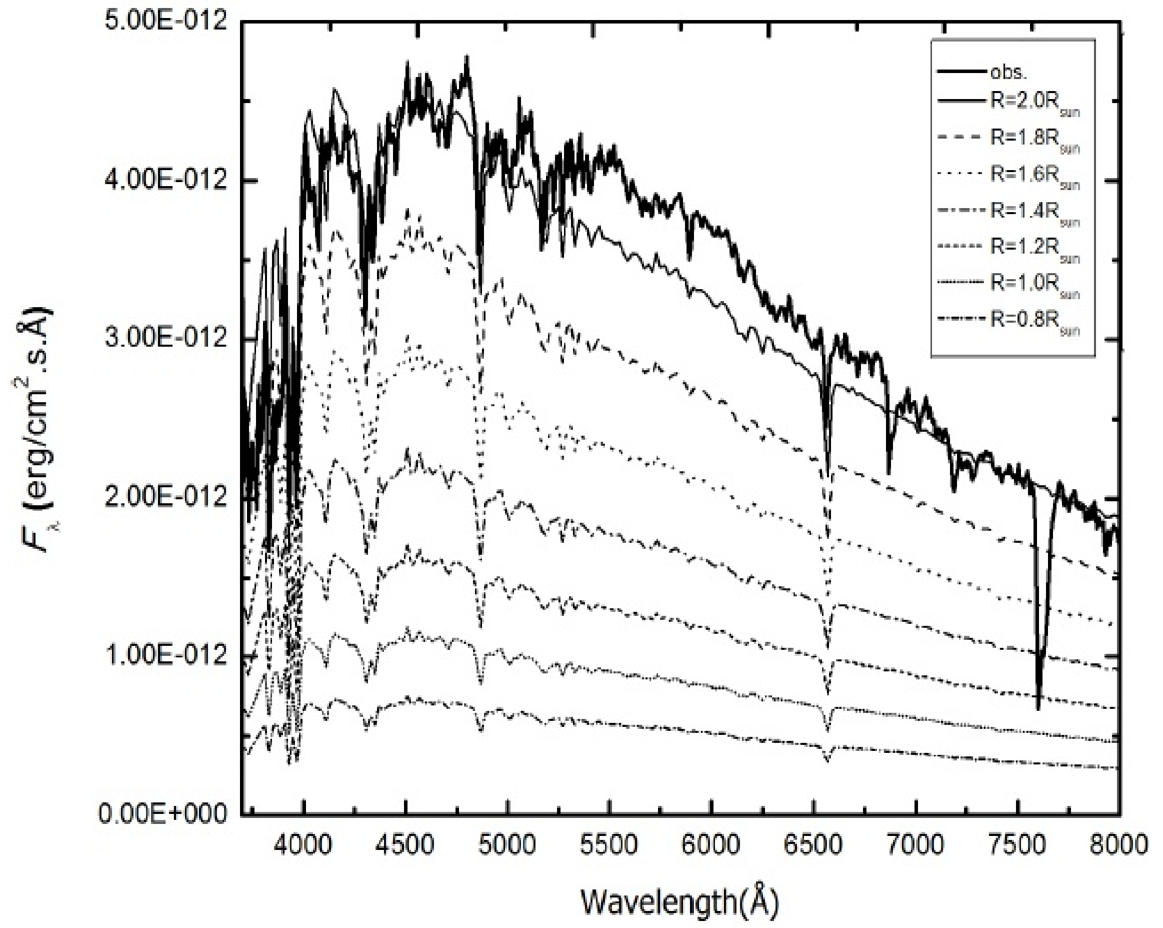


Figure 3.3
Effect of changing radii on the SED of the star

3.2.4 Effects of changing the parallax of the star on SED

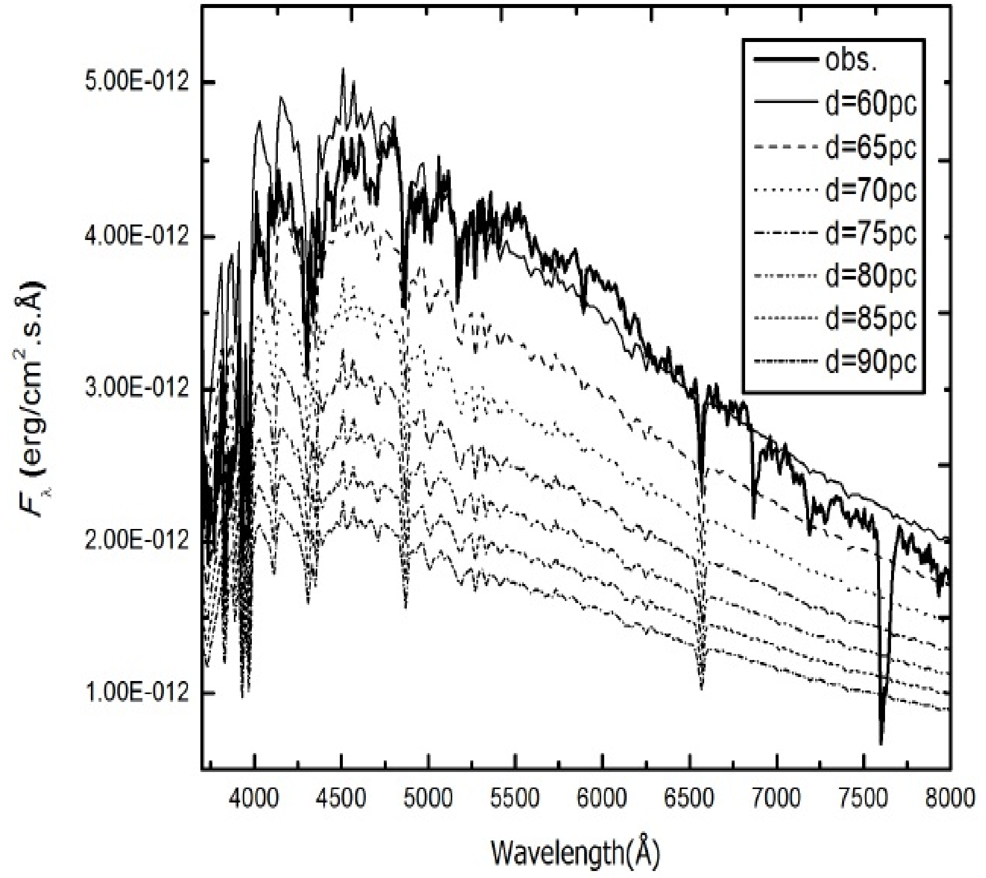


Figure 3.4
Effect of changing distance on the SED of the star

3.2.5 Synthetic SED of different spectral types

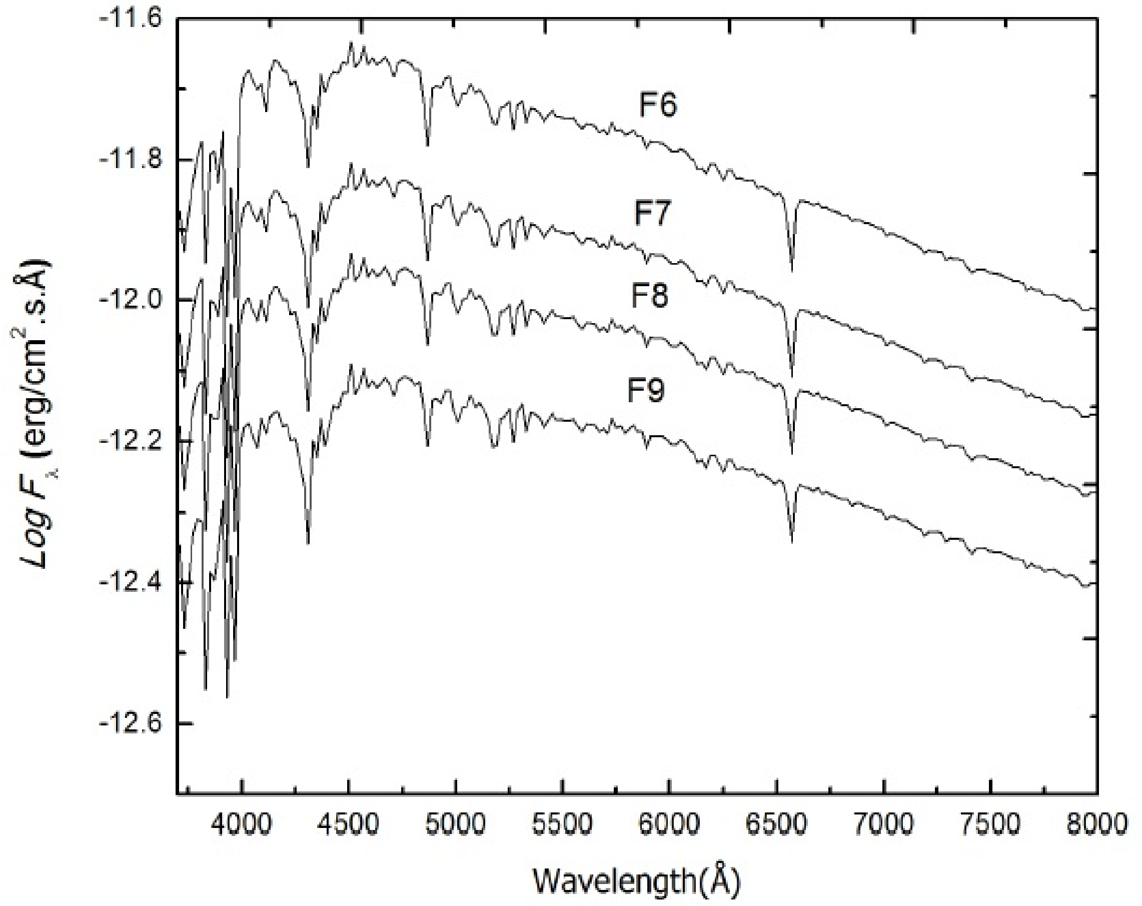


Figure 3.5
SED of different spectral types for a main sequence star

3.3 Atmospheric Modeling

Atmospheric modeling combination with observational results is one of the most recently applied methods to reach the best knowledge about stars and to the determination of the fundamental parameters of stars, such as effective temperature, surface gravity and elemental abundances (Cottrell, 1997).

A model stellar atmosphere is numerical model to understand the outer regions of the stars. The goal of stellar atmospheric modeling is to calculate the physical structure of the outer regions of stars. Those fundamental physical quantities such as radius, effective temperature, separation angle, etc. (LeBlanc, 2010).

3.3.1 Input parameters for model atmospheres:

The magnitude difference Δm can be combined with the entire visual magnitude of the system and Hippracos parallaxes (ESA,1997) in order to obtain absolute magnitudes and spectral types of the individual components of the system, which in turn led to know masses of the system (the mass is one of the most important parameters of the stars). The accuracy of the estimated masses and absolute magnitudes depends, mainly, on the errors of the used parallax.

Table 3.1
Data from SIMBAD and NASA/IPAC

	Hip64838	**Ref**
α_{2000}	$-13^{h}17^{m}29.^{s}853$	SIMBAD
δ_{2000}	$-00^{h}40^{m}33.^{s}83$	SIMBAD
HD	115488	SIMBAD
Tych	4958-1448-1	SIMBAD
E(B-V)	0.026	NASA/IPAC
A_v	0.08	NASA/IPAC
Sp. Type	F0	SIMBAD

NASA/IPAC:http://irsa.ipac.caltech.edu

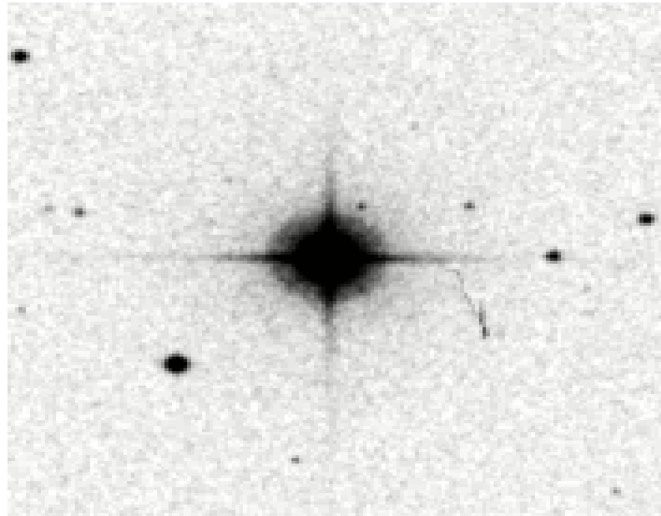


Figure 3.6
Hip64838 in Space

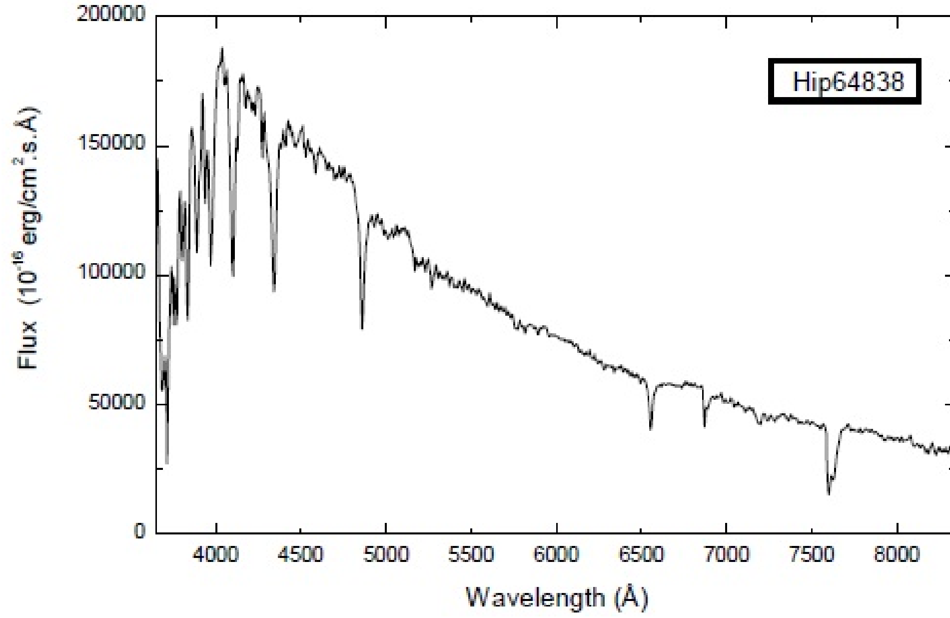


Figure 3.7
Spectral energy distribution (absolute flux) of the system Hip64838(Al-Wardat, 2002b)

Under the assumption that all components of the system are on the main-sequence stars (MS) combining visual magnitude (m_v), magnitude difference (Δm),parallax (π) and radii a long with atmospheric modeling will help in building a synthetic spectral energy distribution (SED) for each component and hence for the entire system. This entire synthetic SED will compare with the observational one in an iterated method (including all input parameters) tells we get the best fit.

3.3.2 Model atmosphere parameters of Hip64838

Using the composite photometry of the system $m_v = 6.^m36$ from the SIMBAD (see Table 3.2) and we adopted for this system $\Delta m = 0.^m73$ as the average of all Δm measurements under the filter 550nm/40 (see Table 3.2).

Table 3.2
Data from Hipparcos and Tycho Catalogues

	Hip64838 HD115488
$V_J\,(Hip)$	$6^m.36 \pm 0.06$
$(B-V)_J\,(Hip)$	$0^m.260 \pm 0.006$
B_T	$6^m.66 \pm 0.004$
V_T	$6^m.380 \pm 0.004$
$(B-V)_J\,(Tych)$	$0^m.255 \pm 0.005$
π_{HIP}	12.28 ± 0.77

Table 3.3
Entire synthetic Johnson, Tycho and Stromgren magnitudes and color indices of the system 64838 (Al-Wardat, 2008)

System	filter	HIP 46838
Johnson	V_J	6.49
Tycho	B_T	6.71
	V_T	6.50
	$(B-V)_T$	0.21
Stromgren	v	6.85
	b	6.54
	y	6.47
	v-b	0.31
	b-y	0.08

Table 3.4
Magnitude difference between the components of the system Hip64838, along with filters used to obtain the observations

Δm	**filter (λ/Δλ)**	**Ref**
0.62	550/40	Hor2008
0.48	754/44	Hor2008
0.99	550/40	Hor2011b
0.58	550/40	Hor2011b
0.40	551/22	Tok2010
0.46	562/40	Hor2011b
0.31	642/40	Hor2011b

Table 3.5
Basic Parameters resulted from calculation Hip64838.see appendix (IV)

Parameters	Hip64838
Δm	0.73
Num.used filter	Average of all filter 550*nm*/30*nm*
M_v^a	$2.^m23$
M_v^b	$2.^m96$
M_{bol}^a	$2.^m63$
M_{bol}^b	$3.^m36$
$L_a(L_\odot)$	$L_a = 7.0L_\odot$
$L_b(L_\odot)$	$L_b = 3.6L_\odot$

To calculate the radii and gravity acceleration (log g) of the components of the system, we need their effective temperatures and mass. These effective temperature were derived from the empirical $(T_{eff} - M_{bol})$(Gray, 2005) assuming that our stars are main sequence stars depending on the shape of their spectra, So

$$T_{eff}^a = 8057K \ , \ T_{eff}^b = 6938K$$

The masses of the system were derived from the empirical (Sp−M) relation depending on the table (Gray2005) as:

$$M_a = 1.96M_\odot \ , \ M_b = 1.61M_\odot$$

Hence, the radii can be calculated using the following relation:

$$\log(R/R_\odot) = 0.5\log(L/L_\odot) - 2\log(T_{eff}/T_\odot)$$

$$R_a = 0.98R_\odot \ , \ R_b = 1.86R_\odot$$

Where $T_\odot = 5777K$ was used.

When combined radii with the masses of the system, we get the gravity acceleration at the surface of the components using the following relation:

$$\log g = \log(M/M_\odot) - 2\log(R/R_\odot) + 4.43$$

$$\log g_a = 4.74 \ , \ \log g_b = 4.10$$

The derived values of the effective temperatures the radii and the gravity acceleration allowed us to construct the model atmospheres of each

component of the system using ATLAS9 line-blanketed plane-parallel model by (Kurucz, 1993).
The basic parameters for the components of Hip64838 are:

$$T_{eff}^{a} = 8057K \ , T_{eff}^{b} = 6938K$$

$$\log g_{a} = 4.74 \ , \ \log g_{b} = 4.10$$

$$R_{a} = 0.98R_{\odot} \ , \ R_{b} = 1.86R_{\odot}$$

And Hipparcos trigonometric parallax ($\pi_{Hip} = 12.28$) (mas: milli arc second).

3.4 Primary Spectral Analysis

To analyze of Hip64838 system we use ATLAS9 line-blanketed plane-parallel model by input system parameters, effective temperature, radii, and gravity accelerations to modulate atmospheres of component of the system(Kurucz, 1993) .

The theoretical SED of each component was constructed alone, and then combined with that of the second component to get the entire SED using a relation represents the total energy flux emitted from the two components of a binary star located at a distance d from the Earth(Al-Wardat, 2002a, 2003)

$$F_{\lambda}.d^{2} = H_{\lambda}^{a}.R_{a}^{2} + H_{\lambda}^{b}.R_{b}^{2}$$

Where H_{λ}^{a}, H_{λ}^{b} is the flux from a unit surface for each component .
We use the previous Sequence to get this graph
We use the previous Sequence to get this graph:

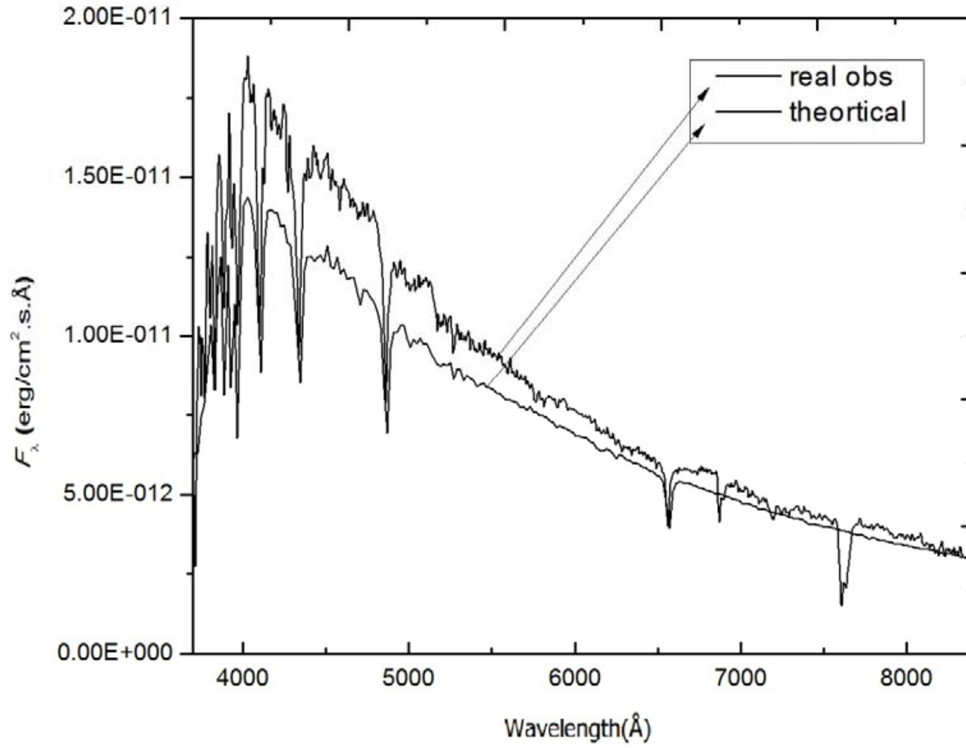


Figure 3.8
Primary Spectra

From the previous entire SED doesn't Corresponds to the observational One and it's so far from the spectrum, its Clarify that input temperature is different than real temperature. So to get the best fit I changing the parameters which SED is proportional with.

3.5 Exact synthetic spectra

In order to get these best fit, hundreds of models were built and used to form SED's. Each time, the synthetic SED was compared with the observational one in an iterated method tells we reacted the best. to compare between the both SED ,we take in account many point :

1. The shape of the peak.
2. Spectral sidelines.
3. Δm Should be very close to the observational one $(\Delta m = V_J^b - V_J^a)$.
4. $B-V$ Of the entire SED should be the same as the observational one.

There are two ways to find the best fit:

1. Fixing the parallax as given by Hipparcos modified data and changing the radii tell we get the best absolute flux (van Leeuwen, 2007).
2. Fixing the radii as given by (Gray, 2005) tables or the standard (T-L-R) equation for the main sequence stars, and changing the parallax.

And from the best fit by second way we get:

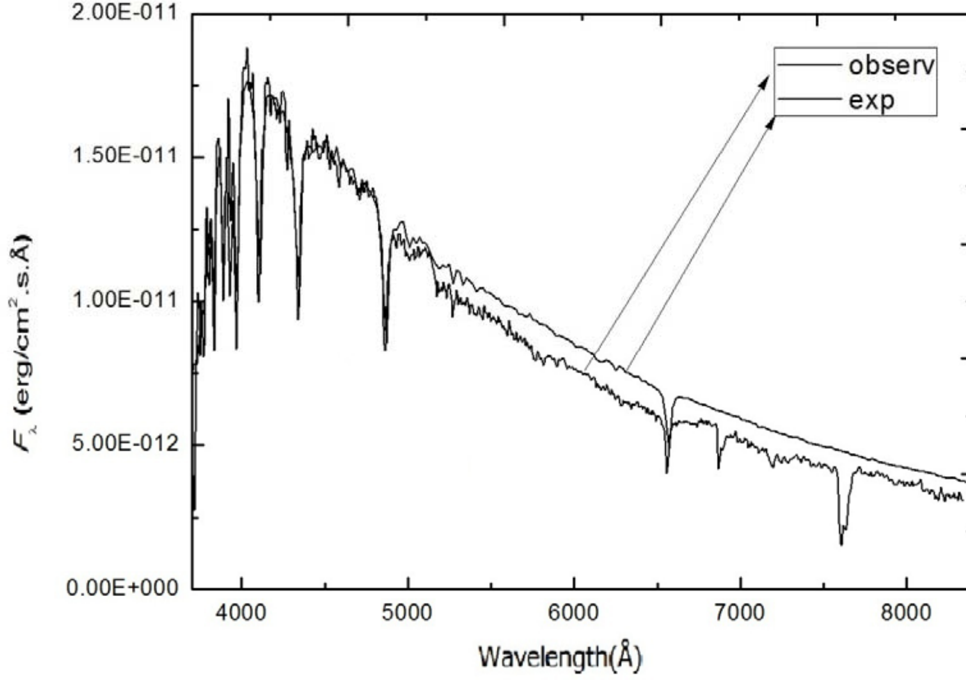


Figure 3.9
Exact synthetic spectra Flux

Figure(3.9) output from apply this parameter

$$T_a = 7950K \qquad T_b = 7025K$$
$$R_a = 1.68R_\odot \quad R_b = 1.57R_\odot$$
$$d = 72.9pc$$

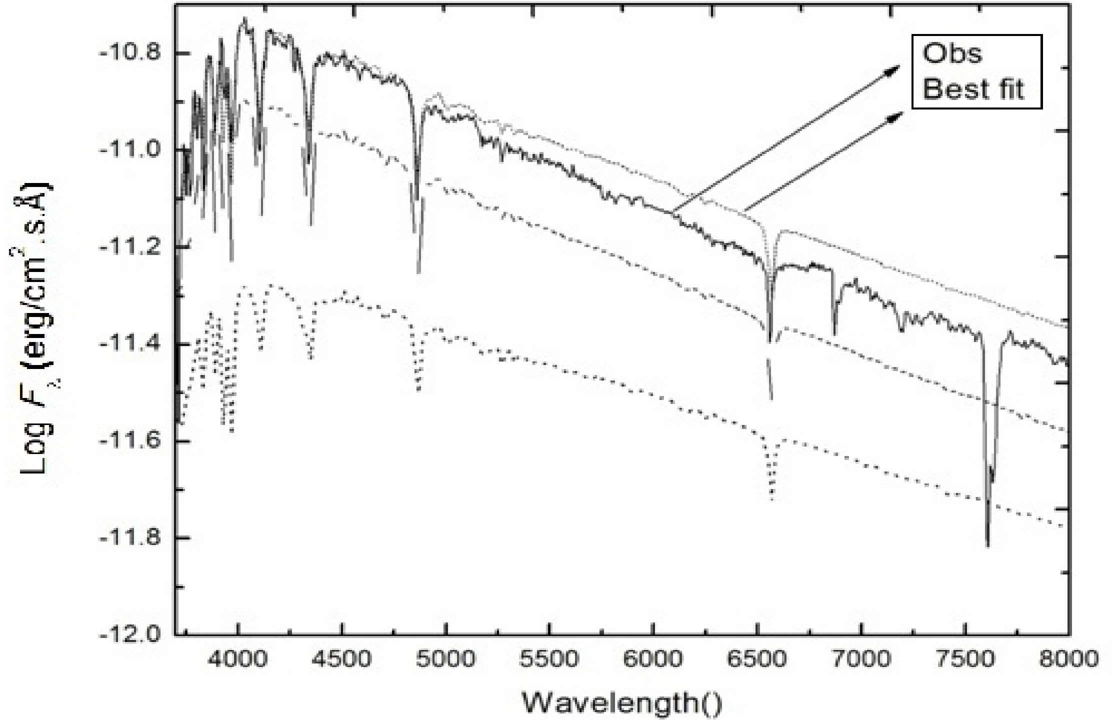


Figure 3.10
Exact synthetic spectra log Flux

The best fit by using these parameters:

$$T_a = 7950K \qquad T_b = 7025K$$
$$Logg_a = 4.2 \quad Logg_b = 4.3$$
$$R_a = 1.68R_{\odot} \qquad R_b = 1.57R_{\odot}$$

To get best fit we found these two ways, changing parallax and changing the radii given by (Gray, 2005).

It is worthwhile to mention here that changing the parallax of the system highly affects the values of the components radii, raising up their error values. Thus, the values of the radii are highly dependent on the Hipparcos parallax measurements, which are, in some cases, distorted by the orbital motion of the components of such systems as noted by(Shatskii & Tokovinin, 1998) ,who puts the parallax subject to change instead of a postulated one.

So, we calculated the absolute flux using Gray (2005) radii as postulate values leaving the parallax subject to change. Keeping in mind the values of

the total observational Δm ,V_J ,$(B-V)_J$, V_T and B_T as our goal in achieving the best fit between the synthetic and observational total absolute fluxes, we reached that using the following set of parameters:

$$T_a = 7950K \qquad T_b = 7025K$$
$$Logg_a = 4.2 \qquad Logg_b = 4.3$$
$$R_a = 1.68R_{\odot} \qquad R_b = 1.57R_{\odot}$$
$$d = 72.9pc$$

By apply previous parameters in main sequences equation (T-L-R) to get the individual luminosities depending and the bolometric magnitudes for each component:

$$L_a = 10L_{\odot} \qquad L_b = 5.4L_{\odot}$$
$$M^a_{bol} = 2^m.25 \qquad M^b_{bol} = 2^m.92$$

$M^{\odot}_{bol} = 4^m.75$ Bolometric magnitude for the sun

To find the spectral types for the components of the system we use(Gray, 2005)or(Lang, 1992) (Sp-T_{eff}) relation

$$Sp_a = A7$$
$$Sp_b = F0$$

And we find the mass for

$$m_a = 1.944m_{\odot}$$
$$m_b = 1.60m_{\odot}$$

Additionally, we can calculate the density ratio of the components as follows:

$$\rho_a = 0.88\rho_b$$
$$\rho = \frac{m}{V} = \frac{m}{\frac{4}{3}\pi R^3}$$
$$\rho_a = \frac{m_a}{V_a} = \frac{1.944m_{\odot}}{\frac{4}{3}\pi 1.68R_{\odot}{}^3} = \frac{1.944}{(1.68)^3} \text{X} \frac{m_{\odot}}{V_{\odot}} = 0.41\rho_{\odot}$$

So $\rho_b = 0.466\rho_{\odot}$

Table 3.6
Comparing the fundamental parameters estimated using speckle interferometry with those estimated using atmospheres modeling

System	HIP64838			
The method	ATM. Modeling		Speckle interferometry	
Component	Comp.a	Comp.b	Comp.a	Comp.b
Effective Temperature T_{eff} (K)	7950K	7025K	8057K	6938K
Radius ($R_{\odot}$)	1.68	1.57	0.98	1.86
Gravity acceleration ($Logg$)	4.2	4.3	4.73	4.1
Luminosity $L(L_{\odot})$	10.0	5.4	3.6	7.0
Bolometric magnitude (M_{bol})	2.25	2.92	2.23	2.96
Absolute magnitude (M_v)	2.20	2.94	2.23	2.96
Mass $(M_{\odot})$	1.944	1.60	1.97	1.58
Sp.type	$A6$	$F1.5$	$A6$	$F1.5$
Parallax (mas : milli arc second)	13.7		12.28	

A comparison between two methods for the parameters of the components of the system Hip64838.

Table 3.7
The final parameters for HIP64838

system	HIP64838	
Component	Comp.a	Comp.b
Effective Temperature T_{eff} (K)	7950K	7025K
Radius ($R_{\odot}$)	1.68	1.57
Gravity acceleration ($Logg$)	4.2	4.3
Luminosity $L(L_{\odot})$	10	5.4
Bolometric magnitude (M_{bol})	2.25	2.92
Absolute magnitude (M_v)	2.2	2.94
Mass $(M_{\odot})$	1.944	1.60
Sp.type	A7	F0
density $(\rho_{\odot})$	0.41	0.466
Parallax (mas)	13.7	

3.6 Formation and evolution of the system

To get an idea of the evolutionary stars of the system, its age and masse, we plot the system's components on the isochrones computed from evolutionary tracks models where the relationship between the mass and luminosity for the stars gives a general idea of the age of the star.

Whatever the model of formation, the complete formation process of binary and multiple system consists of two phases: the fragmentation is only the first step in the formation of a binary or multiple system which will become the components of the binary and multiple system, and the later evolution, consisting of accretion and migration, which will fix the final masses of the components and the orbital parameters of the systems.

Chapter Four
Results and discussions and Recommendations

4.1 Results

The complete parameters of the systems HIP46838 components (effective temperature, luminosity, spectral type, mass, gravity acceleration) were estimated, and the results were as the following table.

Table 4.1
The complete parameters of the systems HIP46838

system	**HIP64838**	
Component	**Comp.a**	**Comp.b**
Effective Temperature T_{eff} (K)	7950K	7025K
Radius ($R_{\odot}$)	1.68	1.57
Gravity acceleration ($Logg$)	4.2	4.3
Luminosity $L(L_{\odot})$	10	5.4
Bolometric magnitude (M_{bol})	2.25	2.92
Absolute magnitude (M_v)	2.2	2.94
Mass $(M_{\odot})$	1.944	1.60
Sp.type	A7	F0
density $(\rho_{\odot})$	0.41	0.466
Parallax (mas)	13.7	

We built a synthetic spectral energy distribution (SED) for each component of the system, depending on kurucz 1994 solar abundance line blanketed model atmospheres.

We combined the individual synthetic SEDs in order to get the totalsynthetic SED of the system.

We compared between total synthetic SED for the system Hip 64838 with the observational one.

we got the best fit between the total observational spectral energy distribution (SED) and the synthetic one using the iteration method of different sets of parameters.

We calculated magnitudes and color indices of the entire system and individual components, in different photometrical systems such as UBVR Johnson-Cousins, uv by Stromgren and BV Tycho by using IDL program.

Comparison between the synthetic magnitudes and colors with the observational ones in above photometrical systems.

The positions of systems components on the evolutionary tracks and isochrones of (Girardi, et al., 1999)were assigned, and their ages were estimated.

4.2 Conclusion

The theoretical SED's of the individual component of Hip64838 systems were build for the first time using atmospheres modeling combination with the results of spectrophotometry. The method depends on getting the best fitting between the observational entire SED's and the theoretical ones built using plane-parallel model atmospheres.

The method uses the magnitude differences between the components and the mass sums of the systems measured by means of the entire spectral energy distributions and apparent magnitudes of the systems measured by spectrophotometry to build individual theoretical SED for each of the subcomponents using Kurucz (1993) line-blanketed plane-parallel model atmospheres. From which we estimate the complete set of the fundamental parameters of each component.

The astrophysical importance of studying these system arises from the need for accurate determination of the fundamental parameters of this components, which will improve our knowledge about the statistical dependencies of the nearby solar type stars, thus the formation and evolution of binary and multiple systems.

4.3 Discussion

The best fit between the total synthetic SED and the observational one represents our main tool in estimating the physical parameters of the system, so there should be a number of criteria for the judgment of the best fit, these are:

A. The shape of the continuoum (Planck's curve).
B. The spectral lines profiles.

The main struggle point in the analysis of the system was the parallax. Where we found a problem with the most well known and reliable trigonometric parallax which was measured by the space observatory Hipparcos.

The problem arises when we tried to get the total flux of the system equations using Hipparcos trigonometric parallax. We found that using Hipparcos value gives higher values of the individual stellar radii, which disagree with standard main sequence tables and equations.

We will fix the input radii according to table (Gray,2005) and leaving the parallax to changing until it get fit between two spectra. With respect to masses of the system, the discrepancy arises either by lack of precision the stellar atmospheres theory, or the stellar evolution theory, or both.

4.4 Recommendations

Further, there are some recommendations on this research:

1. To continue the analysis of stellar binary and multiple systems in order to enhance the possibility of revision of the statistical dependencies on the basis of the direct determination of the complete set of fundamental parameters of the components of these systems.
2. To continue observing the system in a systematic way by speckle interferometry or adaptive optics techniques, in order to get new orbital points and magnitude differences, hence to build new orbits and estimate a new dynamical parallax of the system.
3. To include the system in the programs of the new space telescope GAIA for more accurate parallax and magnitude measurements.
4. To continue studying the dynamical masses of systems by using the orbital elements.
5. To continue studying the discrepancy between the spectroscopic masses (atmospheric modeling) and evolutionary masses and comparing them with other masses this got it from the equations of the main sequence.

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Appendix (I).
Basic Concepts in Astrophysics

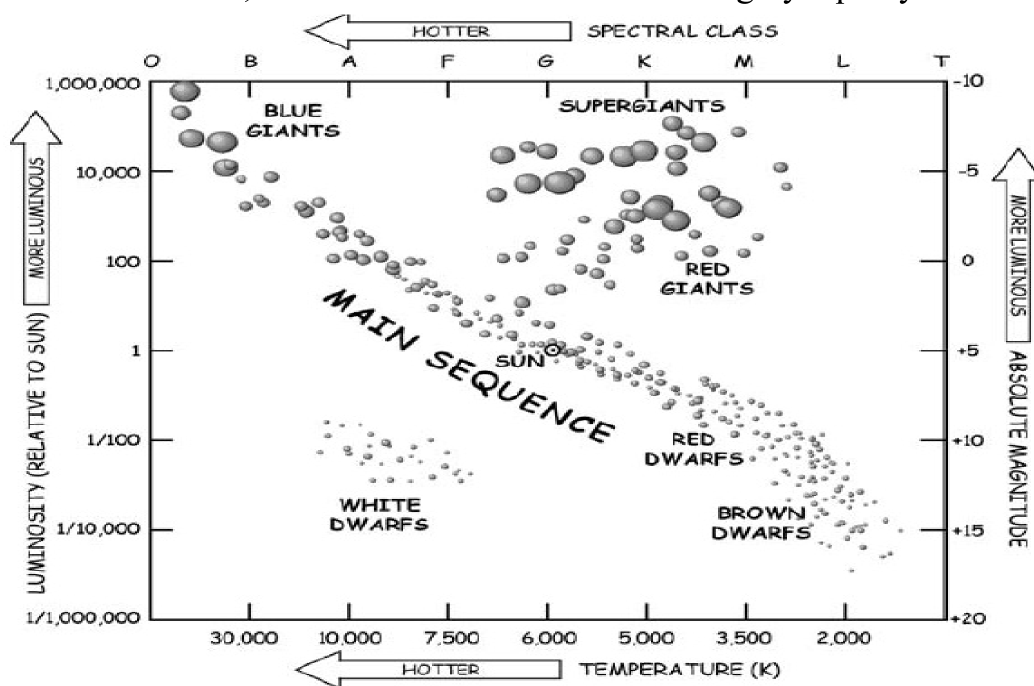
A. Coordinate Systems

Altitude and Azimuth. The altitude is defined relative to the horizon, and is the angle from the horizon to the object. The altitude of an object on the horizon is 0^o, and the altitude of an object directly overhead is 90^o. The point directly overhead (altitude $=90^o$.) is the zenith, and a line running from north to south through the zenith is called the local meridian. Azimuth is the angle around the horizon from north and towards the east. An object in the north has azimuth 0^o, while an object in the west has azimuth 270^o. The altitude and azimuth of an object are particular to the observing location and the time of observation. *Right ascension and declination*. Declination (δ) is like latitude on the Earth, and measures the angle north and south of the celestial equator (an imaginary line in the sky directly over the Earth's equator). The celestial equator lies at 0^o, while the north celestial pole (i.e., the extension of the Earth's rotation axis) is at 90^o. Declination is negative for objects in the southern celestial hemisphere, and is equal to 90^o at the south celestial pole. Right ascension (α) is analogous to longitude. The ecliptic is the plane of the solar system, or the path that the Sun follows in the sky. Because the axis of the Earth is tilted, the ecliptic and the celestial equator are not in the same place, but cross at two locations, called the equinoxes. One of these locations, the vernal equinox, is used as the zero point of right ascension. Right ascension is measured in hours, minutes, and seconds to the east of the vernal equinox. There are 24 hours of right ascension in the sky, and during the 24 hours of the Earth's day, all of them can be seen. Each hour on Earth changes the right ascension of the meridian by just less than 1 hour. (Palen, 2001)

B. **Hertzsprung – Russell Diagram**:

A famous diagram, called the Hertzsprung Russell (hereafter H – R) diagram, shows the relation between the luminosity and the effective temperature of stars. (1873 – 1967) and the American astronomer Henry Norris Russell (1877 – 1957) at the beginning of the twentieth century. The H – R diagram is extremely useful when studying the evolution of stars, since there are well - determined paths along which stars should travel as they evolve.(LeBlanc, 2010) Here, the x□axis is in Kelvin, but sometimes stellar color or spectral class is used. The y□axis is in units of the Sun's luminosity, but absolute magnitude is employed very often. Absolute magnitude is the apparent magnitude of a star that's 10 parsecs (~31.6 ly) distant. Note that temperatures decrease to the right. Stars in the left are hotter; those at the top are more luminous. It's important to understand how stellar colors are

determined. Since the spectrum of stars depends on temperature Spectral classes in HR diagrams are described in to seven classes: O, B, A, F, G, K, M in order of decreasing temperature. In the century since the bases of HR diagrams were first developed, they have become invaluable in the study of stars. For astronomers, a star's location in an HR diagram provides the same depth of insight as for chemists examining an element in the periodic table. It relates hydrogen fusing stars' temperatures, colors and spectral classes with their luminosities, thereby providing insights into their evolution. A star's position in the diagram can indicate its composition, surface temperature, intrinsic brightness, size, mass, lifetime, and evolutionary status. That's a lot of information from a diagram. It's been invaluable in determining the age of various star clusters. Apparent magnitudes can be used if absolute magnitudes are not available, since all stars in a cluster are roughly equally distant.



H-R Diagram

C. Astronomical Catalogue:

Catalogue, are astronomical Tabular compilation of stars or other deep-sky objects, giving their celestial coordinates and other parameters, such as magnitude. (Moore, 2002), the various types of catalogue are distinguished by their content (the kind of sources covered and the parameters given), their context (when, why and how they were created) and their scope (the limiting magnitude).

The first actual star catalogue was published by Ptolemy in the second century; this catalogue appeared in the book to be known later as Almagest

(which is a Latin corruption of the name of the Arabic translation, Almijisti). It had 1025 entries; the positions of these bright stars had been measured by Hipparchos 250 years earlier. (Karttunen & Oja, 2007), Ptolemy's catalogue was the only widely used one prior to the 17^{th} century.

Hipparcos (An astrometric satellite of the European Space Agency (ESA) launched in Aug. 1989 to gather modern data on the position, brightness and other properties of an input catalog of selected stars with an unprecedented level of accuracy. Although its name was an acronym, it was deliberately chosen to recall the ancient Greek astronomer Hippachus, who compiled an important star catalog in the 2nd century BC.) (Daintith & Gould, 2006) for more information about astronomical Catalogue see (Moore, 2002), (Allen & Cox, 2000) .to know more about Hipparcos Catalogue see (Perryman & Press, 2009)

Appendix (II)
Basic parameters

There some parameters must know, before we start modulate atmospheric modelling

Luminosity (L)

The luminosity L_v *at frequency* v is the amount of energy radiated by a body per second at this frequency. The total luminosity L, or simply the luminosity, is the total amount of energy at all frequencies. The luminosity is a property of the star and it does not depend on from what distance it is measured. For example, the luminosity of the sun is 3.8 x10^{26} W. The total amount of energy passing through this sphere (in one second) must be equal to the energy emitted by the star, L. Further, the total energy passing through 1 m^2 (in one second) will be F. Therefore, in this case,

$$L = \pi F d^2$$

Apparent Magnitude (m)

The *apparent magnitude* m is a measure of how bright a star looks to the observer. The apparent magnitude is directly related to the flux density. The apparent magnitude of an object is defined as

$$m = -2.5\log(F / F_{\circ})$$

where F is the flux of the object and $F_{\circ}$ is a preselect level of flux associated with apparent magnitude 0. The apparent magnitude is a dimensionless magnitude. For example, the sun has apparent magnitude -26.73 while the naked eye limit is around 6.5 (the higher the m , the lower the flux density F).

Absolute magnitude (M)

As for the flux, the apparent magnitude of a star depends on how far we are from it. The *absolute magnitude M* of a star is defined as the apparent magnitude at a distance of 10 parsecs. The absolute magnitude is a property of the star directly related to its luminosity.

Visual magnitude and bolometric magnitude

When we measure flux or apparent magnitudes we would like to measure over all frequencies. However, the sensitivity of the detectors is different at different frequencies. This means that we typically only measure a fraction of the total flux. If we measure the apparent magnitude with an instrument which is most sensitive to radiation with a wavelength of 5450 Å we say that we measure the *visual magnitude* m_v. The reason for this terminology is that the human eye is most sensitive at this wavelength.

The *bolometric magnitude* m_{bol} is a theoretical concept. It is equal to the apparent magnitude in a world with perfect instruments, equally sensitive at all wavelengths. The bolometric magnitude would correspond to the actual flux.

Bolometric correction

If the source radiates in such a way that the maximum energy is found at the same wavelength as where the instrument is most sensitive, then the measured value of the apparent magnitude is close to the bolometric magnitude. This is the case when we measure the flux from the sun. The maximum energy from the sun is found at approximately 5000 Å which means that the visual magnitude for the sun is close to the bolometric magnitude. The *bolometric correction* BC is defined as:

$$m_{bol} = m_v + B.C$$

Since the bolometric magnitude is always smaller than visual magnitude, B.C ≤ 0 . Also, BC is small for stars with a temperature close to the temperature of the sun and large for stars that are much hotter or much cooler than the sun. The bolometric correction for the sun is approximately -0.08.

Absolute bolometric magnitude

The absolute bolometric magnitude M_{bol} is defined as the bolometric magnitude at a distance of 10 parsecs. For example, the bolometric magnitude for the sun is

$$m_{bol,\odot} = -26.73 - 0.08 = -26.81$$

since the distance to the sun is $d_{\odot}$ = 4.84 x10^{-6} pc the absolute bolometric magnitude of the sun is about

$$M_{bol,\odot} = m_{bol,\odot} - 5\log d + 5 = 4.75$$

Consider a star with luminosity L and absolute bolometric magnitude M_{bol} and let F_M be the flux for this star at a distance $d = 10$ pc. If $F_{\odot}$ is the flux of our sun at distance $d = 10$ pc then

$$M_{bol} - M_{bol} = -2.5\log(F_M / F_{\odot}) = -2.5\log(L / L_{\odot})$$

where $L_{\odot}$ is the luminosity of the sun, $L_{\odot}$ = 3.8x10^{26} W.

Interstellar absorption

The equation $m = M + 5\log d - 5$ is valid at any frequency and we also have $m_v = M_v + 5\log d - 5$. However, this formula is only correct if the space between the source and the observer is completely empty. If there is interstellar medium between the source and the observer, some of the radiation will be absorbed by the medium. This will make the visual magnitude larger than it otherwise would be. If we define $m_{v\circ}$ as the visual magnitude with no interstellar absorption and we let m_v be the observed visual magnitude ($m_v \geq m_{v\circ}$), we can define the interstellar absorption constant in the V band, A_v as

$$m_{v\circ} = m_v - A_v$$

Where A_v is a positive constant. Thus, we have

$$m_v = M_v + 5\log d - 5 + A_v.$$

Flux and Temperature

Again consider a star with luminosity L and absolute bolometric magnitude M_{bol}.

If we can assume that the star radiates as a blackbody (which is perfectly plausible) then it follows from Planck's law that

$$F = \sigma T^4$$

where T is the effective temperature of the star (in Kelvin) and is σ Stefan-Boltzmann constant, σ=5.67x10-8W $m^{-2}\ K^{-4}$. If R is the radius of the star, then its surface area will be $4\pi R^2$ and $L = 4\pi R^2 F = 4\pi\sigma R^2 T^4$

It then follows that

$$\frac{L}{L_\odot} = \frac{4\pi\sigma R^2 T^4}{4\pi\sigma R_\odot^2 T_\odot^4} = (\frac{R}{R_\odot})^2 (\frac{T}{T_\odot})^4$$

where $R_\odot$ is the radius of the sun. Therefore

$$M_{bol} - M_{bol\odot} = -2.5\log\frac{L}{L_\odot} = -2.5\log(\frac{R}{R_\odot})^2(\frac{T}{T_\odot})^4$$

Appendix (III)
Astronomical Techniques

This is Some Astronomical Techniques Which use study stars

Photometry

is a technique of astronomy concerned with measuring the flux, or intensity of an astronomical object's electromagnetic radiation.(Sterken & Manfroid, 1992) Usually, photometry refers to measurement over large wavelength bands of radiation; when not only the amount of radiation but also its spectral distribution is measured the term spectrophotometer is used.

Photometric measurements can be combined with the inverse-square law to determine the luminosity of an object if its distance can be determined, or its distance if its luminosity is known. Other physical properties of an object, such as its temperature or chemical composition, may be determined via broad or narrow-band spectrophotometry. Typically photometric measurements of multiple objects obtained through two filters are plotted on a color-magnitude diagram, which for stars is the observed version of the Hertzsprung-Russell diagram. Photometry is also used to study the light variations of objects such as variable stars, minor planets, active galactic nuclei and supernovae, or to detect transiting extrasolar planets. Measurements of these variations can be used, for example, to determine the orbital period and the radii of the members of an eclipsing binary star system, the rotation period of a minor planet or a star, or the total energy output of a supernova.

Interferometry

Interferometry refers to a family of techniques in which electromagnetic waves are superimposed in order to extract information about the waves. An instrument used to interfere waves is called an interferometer. Interferometry is an important investigative technique in the fields of astronomy.(Bunch & Hellemans, 2004)

The basic principles behind stellar interferometry should be familiar to any physicist, founded on the wave properties of light as first observed by Thomas Young in 1803. This result is widely known through Young’s two-slit experiment, although two-slits were not used in the original 1803 work.

New capabilities are being applied in a wide variety of astrophysics contexts including fundamental stellar parameters, novel ways to measure distances to stars, probing star formation and evolution, direct detection of extra solar planets, and resolving cores of the nearest active galactic nuclei (AGN) and brightest quasars.(Monnier, 2003)

Astrometry

Astrometry is the branch of astronomy that involves precise measurements of the positions and movements of stars and other celestial bodies. The information obtained by astrometric measurements provides information on the kinematics and physical origin of our Solar System and our Galaxy, the Milky Way.

Apart from the fundamental function of providing astronomers with a reference frame to report their observations in, astrometry is also fundamental for fields like celestial mechanics, stellar dynamics and galactic astronomy. In observational astronomy, astrometric techniques help identify stellar objects by their unique motions. It is instrumental for keeping time, in that UTC is basically the atomic time synchronized to Earth's rotation by means of exact observations. Astrometry is an important step in the cosmic distance ladder because it establishes parallax distance estimates for stars in the Milky Way.

Astrometric measurements are used by astrophysicists to constrain certain models in celestial mechanics. By measuring the velocities of pulsars, it is possible to put a limit on the asymmetry of supernova explosions.

Astrometry is responsible for the detection of many record-breaking solar system objects. To find such objects astrometrically, astronomers use telescopes to survey the sky and large-area cameras to take pictures at various determined intervals. By studying these images, they can detect solar system objects by their movements relative to the background stars, which remain fixed.

In 1989, the European Space Agency's Hipparcos satellite took astrometry into orbit, where it could be less affected by mechanical forces of the Earth and optical distortions from its atmosphere.

Operated from 1989 to 1993, Hipparcos measured large and small angles on the sky with much greater precision than any previous optical telescopes. During its 4-year run, the positions, parallaxes, and proper motions of 118,218 stars were determined with an unprecedented degree of accuracy. A new “Tycho catalog” drew together a database of 1,058,332 to within 20-30 mas (milliarcseconds). Additional catalogues were compiled for the 23,882 double/multiple stars and 11,597 variable stars also analyzed during the Hipparcos mission .

Appendix (IV)
Calculation

$\pi = 12.28$, So by using $d = 1/\pi$

$d = 1/(12.28\times10^{-3}) = 81.9pc$

$\frac{F_a}{F_b} = 2.512^{-\Delta m}$

Δm Where F_a, F_b is the flux for both components, Δm magnitude difference .

$\Delta m = 0.73$ The average value for all filters.

$V_J = m_v = 2.5\log(F_a + F_b)$

$V_J = m_v = 6.36$,

$$m_v^a = m_v + 2.5\log(1+10^{-0.4\Delta m})$$

$$m_v^b = m_v^a + \Delta m$$

Then we find $m_v^a = 6.81$, and $m_v^b = 7.54$.

$M_v = m_v + 5 - 5\log(d) - A_\upsilon$

$M_v^a = 6.81 + 5 - 5\log(81.4) - 0.08 = 2.23$

$M_v^b = 7.54 + 5 - 5\log(81.4) - 0.08 = 2.96$

m_v, M_v are apparent and absolute magnitudes respectively, d is the distance to the star, while A_v is called the interstellar reddening .
The bolometric magnitudes can be derived from the absolute magnitudes if we know the bolometric correction

$$M_{bol} = M_v + B.C$$

$M_{bol}^a = 2.63$ and $M_{bol}^b = 3.36$.

The absolute bolometric magnitude can be expressed in terms of the luminosity.

$$M_{bol}^* - M_{bol}^\odot = -2.5\log(L_*/L_\odot)$$

where M_{bol}^* is the bolometric magnitude for star, $M_{bol}^\odot$ is the bolometric magnitude of the sun, L_* is the luminosity for star and $L_\odot$ is the luminosity of the sun. Where $M_{bol}^\odot = 4.75$ was used. We get $L_a = 7.0L_\odot$, $L_b = 3.5L_\odot$ from table gray 2005 we get the effective temperature of a star (T_{eff}).

We found $T_{eff}^a = 8057K$, $T_{eff}^b = 6938K$ and this is the theoretical temperature.

And the mass of the both component is $M_a = 1.97M_\odot$, $M_b = 1.61M_\odot$.

The radii are the function of the luminosities and temperatures:

$$\log(R_*/R_\odot) = 0.5\log(L_*/L_\odot) - 2\log(T_*/T_\odot)$$

Then $R_a = 0.98R_{\odot}$, $R_b = 1.86R_{\odot}$

We can calculate the gravity acceleration by using this equation:

$$\log g_* = \log(M_* / M_{\odot}) - 2\log(R_* / R_{\odot}) + 4.43$$

We get $\log g_a = 4.74$, $\log g_b = 4.10$